SPINEL, AN OVERLOOKED CRYSTALLINE PHASE OF IGZO

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Key Words: Semiconducting oxides, IGZO, channel, polycrystalline, spinel

In the family of semiconducting oxides, $InGaZnO_4$ (IGZO) is most attractive due to the absence of mobile holes and the preservation of a relative high electron mobility when the material is in the amorphous phase. Especially this last characteristic enables low deposition temperature (T_d), beneficial for the application as semiconducting channels of thin film transistors (TFT) in optical displays and 3D memory elements. However, a disadvantage related to the amorphous phase is the distribution of bonding energies of oxygen anions, which is directly related to the distributed distances with respect to the neighboring metal cations [1], leading to free electron formation readily at low temperature. In contrast to amorphous IGZO, the oxygen sites in crystalline IGZO have unique bonding energies, but crystallization of amorphous IGZO into polycrystalline IGZO did not improve TFT performance. Instead, an improved oxygen stability is claimed for the semi-crystalline phase, better knowns as C-axis aligned crystalline (CAAC), which is readily obtained by physical vapor deposition (PVD) using high temperature (~300 °C) and a high oxygen flow. Recently, it was found that this phase emerges from the metastable phase of spinel IGZO [2]. Spinel IGZO is typically formed at lower temperatures (200 °C) when the indium atoms are lacking energy to separate into InO_x planes that are characteristic for the CAAC phase. The spinel structure is the stable crystalline phase for GZO, but replacement of Ga by In decreases this stability.

Using a templating effect, polycrystalline films of spinel IGZO films were obtained by physical vapor deposition (PVD) under process conditions that normally provide amorphous films. We show how an optimized texture of the GZO template increases the process window for spinel IGZO. The preferential orientation of spinel crystals indicates the preference for a triangular arrangement of the metal cations inside planes parallel to the substrate, similar as in C-axis aligned crystalline IGZO. The optimized texture stimulates the growth of spinel IGZO in PVD. Moreover, by using different templates, like MgO, the texture of the spinel IGZO can be forced into a different orientation enabling further study on the formation of this metastable phase.

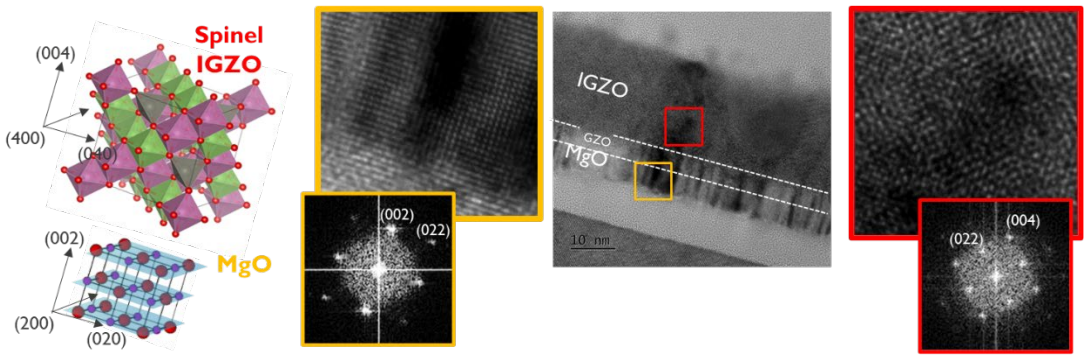

Figure 1, cross-section TEM image showing the altered texture of spinel IGZO by changing the preferential orientation of the GZO template. Insets show the electron diffraction indicating the orientation of texture as given by the cartoons.

In this work we show that the 'overlooked' phase of spinel IGZO is a more representative model and less complicated model to approach amorphous IGZO and can therefore be used to investigate the physical and electrical properties of amorphous IGZO better. This is further demonstrated by reducing spinel IGZO by annealing in hydrogen ambient, forming In_2O_3 and metallic indium with similar preferential crystal orientations. Also, the grain boundaries of the polycrystalline phase of spinel induces less scattering with optimized texture compared to the polycrystalline hexagonal phase which normally crystallizes from the amorphous phase.

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